[Proc. Roy. Soc. Victoria 34 (N.S.), Pt. II., 1922].

Art. XII.—*Local Rain Producing Influences under Human Control in South Australia.*

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(With Map.)

[Read 8th September, 1921].

In a previous paper the author has brought several lines of proof to show that various influences in Victoria were having a marked effect upon the rainfall. The chief of these were the substitution in the Mallee of crops and grass for the drought-resistant forest covering, and irrigation, both natural and artificial. One of the proofs relied upon was a map showing for all stations available the departures of the mean rainfall for the decade 1910-1919 from that of a standard 30-year period, 1885-1914. This appeared to show remarkably well the effects looked for, that is, all areas in lee of, or S.E. from one with increased cultivation or irrigation, showed a marked increase in the rainfall, up to 15 per cent. in the most favoured cases. But there were increases just beyond the Victorian border in South Australia for which no explanation was available. In order to see if any light might be thrown upon this, I undertook the task of analysing the South Australian rainfalls in the same way as I had already done those of Victoria and the southern and western parts of New South Wales. This revealed an area of marked rainfall improvement, lying south-east from Lake Torrens, and embracing more especially the eastern portions of the Upper North, where it ranged as high as 20 per cent. This area seems to be continuous with the Victorian areas of improvement, in which case we have a long strip lying north-west and south-east, stretching from the sources of the Murray to Lake Torrens, or at least to the highlands of the Upper North, giving a total length of over 600 miles. It was found too, that as in New South Wales, north from this area the rainfall had markedly decreased, deficiencies of 14 per cent. being common, and that to south-west, as in Victoria, the areas

dependent mainly upon "southern" disturbances for their rains showed a very definite decrease. We therefore have in South Australia and New South Wales a belt of country some 250 miles long and 70 miles wide which has had during the decade, in spite of a general downward tendency elsewhere, a decided increase in its rainfall.

Another improved strip, again lying N.W. and S.E., and therefore parallel to that just defined, begins on the west side of Spencer Gulf at Waratta Vale, some 40 miles north of Port Lincoln, and includes the foot of Yorke Peninsula and the eastern half of Kangaroo Island.

In looking for causes for these rainfall improvements, it is evident that irrigation can be disregarded. No serious attempts at irrigation have been made in South Australia, excepting, of course, those now in progress on the Murray, which in any case could only help Victoria.

We have to consider, therefore, only the alteration in the surface; the substitution of crops or grass for Mallee scrub or other drought-resistant vegetation, and the variations in the water supplies of the great inland lakes. The settlement of the country has brought about considerable changes in these respects. Unfortunately I have so far been able to get but little direct information more than that contained in the Statistical Registers, which deal only with production.

It is interesting to note that in general where throughout the 30-year period, 1885-1914, land occupation was complete and but little progress shown in cultivation and stock raising, there is also no improvement in the rainfall in lee of the area. This applies to the southern half of the country between St. Vincent's Gulf and the Murray River. County Adelaide, for example, has been practically stationary from 1884 to 1918 as regards horses, cattle, sheep and the area under cultivation.

Going northward, we find Counties Gawler and Light have made only very trifling increases in stock, though the years 1909-18 show a 35 per cent, increase in the area under cultivation. The Lower North (lat. 33-34) also shows an almost stationary condition as regards stock, but considerable progress in agriculture, the increase in area amounting to nearly 60 per cent. There is a definite rainfall improvement of up to 9 or 10 per cent. in lee of these areas, or over a N.-S. strip of 120 miles long, and about 20 miles wide.

The Upper North (lat. 31½ to 33) was so badly hit by the droughts of 1895-1902, that its cultivated area declined from 800,000 to about 500,000 acres, or by nearly 40 per cent., and it also suffered stock losses from which it took many years to recover. Even yet this division, though showing rapid increase of late, carries scarcely more stock than in those early years, 1885 to 1890, and less than in 1891 and 1892. As regards the effects from growing crops, it is evident that this cannot be great, at all events in the Upper North, unless we take into account the greatly increased vigour of growth due to recently improved cultivation methods, and the use of fertilisers. These certainly tend to produce far more vigorous growth during the spring months, and favour later sowing.

A not improbable factor is, however, the clearing of the country, which improves convectional action, and therefore makes thunder-showers of more likely occurrence. In spite of the stationary or retrograde conditions of agriculture, the needs of stock have probably made progress in ring-barking and scrub-clearing continuous so that the area of cleared hilly country should be steadily increasing.

Influence of the Lakes.

The foregoing are probable contributory factors, but the lie of the area of greatest rainfall improvement points distinctly to Lake Torrens as its chief origin. With regard to the state of this Lake or of L. Frome, which should share the same fortune, I have been able so far to get little definite information, though various people, some with 40 or 50 years' experience of the interior, most of whom were interviewed by Mr. Bromley, the State Meteorologist, have contributed their impressions. All agree that Lakes Torrens and Frome are rather immense salt pans than true lakes, and only rarely show any extensive areas of water surfaces. Mr. Price, of Frome Downs, writes as follows: "There are about 20 big creeks which, after rain in Flinders Range, empty into Lake Frome. This water all disappears in a few hours after the creeks cease running. The Lake is always very boggy, and no animal can cross it." Lake Torrens appears to behave much in the same way.

It would seem then that the water discharged from time to time into these depressions goes to dilute a semi-liquid mass, the water constituent of which being intensely salt and of high

specific gravity, is capable of holding in suspension, and also preserving much of what the creeks, when flooded, bring down. The rate of evaporation would naturally be influenced by the amount of dilution. The lake beds could hardly remain at all porous, and owing to the absence of vegetation and animal life, either within the lake area or on the shores, the choking of the pores must be permanent. That is, the fine muddy particles have brought about the condition aimed at by the Mallee farmer who "puddles" his dam. Lake Eyre, being fed from such vast areas, is more truly a lake, and, according to Mr. Allen, of Warrina Station, is now fairly full, but that happens only rarely. Mr. T. Hogarth, who has had 50 years' experience of the district, has only seen the Lake filled twice during that time. It also forms such a boggy environment as to make the water unapproachable under ordinary conditions. This and mirage effects make it hard to ascertain the state of this or any of these lakes.

Run-off Improving.

It seems highly probable on various grounds that both Torrens and Frome are now impounding much more water than formerly. Experiences in Victoria go to show that settlement is effecting great changes in the run-off from the various river drainages. The clearing off or killing of the timber has made the springs better water providers, and the destruction of the trees, coarse grasses, reeds, etc., on the stream banks has caused the channels to deepen. Forty or fifty years ago the upper portions of the Avoca River and its tributaries consisted of shallow, and often grassy, channels, connecting large, deep water holes, providing permanent reservoirs, and through their large total capacity presumably holding back very considerable quantities of water which otherwise would have been poured on to the lower plain country. These water holes provided a paradise for anglers, especially school boys. They now hardly exist. Deep gutters have been cut from pool to pool, and the final result is a thread of water, almost constant in volume, with scarcely a pool of sufficient magnitude to shelter a decent sized fish. There is, of course, some compensation in the fact that the more permanent flow of the springs, the better protection from the sun, and the lessened demands of riverside vegetation cause more water to reach the river's final destination, and I anticipate

that these factors are operating in connection with the lakes of South Australia.

Mr. W. E. Abbott, of Wingen, New South Wales, in various papers read before the Royal Society of New South Wales, has given many emphatic proofs of the effects of ring-barking in increasing the flow from springs, and making permanent the flow of streams previously only intermittent.

The Willochra Creek.

The chief source of water supply for Lake Torrens seems to be the Willochra Creek, which drains a belt of country extending south as far as Booleroo, and north as far as Hawker, two stations about 70 miles apart. The area of this can hardly be less than 2000 square miles. It is, of course, rather a dry area. the average annual rainfall ranging from 12 inches at Hawker, to 16 inches about Booleroo, but is liable to have quite a wet climate for months at a time. For instance, at Booleroo periods of six months' duration in 1916 and 1917 gave 17½ and 15 inches respectively; 5 months gave 12 inches in 1920, and 13 inches in 1921; 4 months in 1909 gave 13 inches; 3 months gave, in 1889, 12½ inches; in 1893, 11.6 inches; in 1908, 10 inches, and so on. Hawker has similar records: 14 inches in 3 months in 1889; 13 inches in 4 months in 1892; 15.2 inches in 5 months in 1916; 13.3 inches in 4 months in 1917; 20.4 inches in 6 months in 1920; and 14 inches in the first 5 months of 1921. These are quite sufficient to turn the creek into a very considerable river during these periods.

"Run-off" Rains.

Failing actual data, I ventured on an estimate of the variations in the water supply of Lake Torrens, based upon the probable run-off from the Willochra Creek basin, using the rain stations Booleroo, Quorn and Hawker. This required some assumptions of a very general character. The basin being well drained, I adopted as "run-off" falls in winter, anything over 2 inches for the first month, and 1½ for each consecutive month following, and in summer 3 inches for the first month, and 2 inches for each following month. This probably errs on the side of moderation, for falls of 2 or 3 inches are not uncommon in one day, but at all events it provides a fairly definite scale by which to compare the periods. The first really wet period was from

1889 to 1893, giving a total "run-off" rain of 31.0 inches. This was followed by a long dry spell of 12 years, 1894 to 1905, giving only 15½ inches altogether. The drought ended in 1902, but the "run-off" rains for 1903 to 1905 were small, only totalling 6.0 inches. From 1906 to 1910, a wet period, the "run-off" was 21½ inches; from 1911 to 1915, a very dry five-year period, only 2.4 inches; from 1916 to 1917, two very wet years, 15.7 inches; from 1918-1919, only 1.4 inches, and during 1920, and up till May, 1921, a very wet period, 17.0 inches. The lake should, therefore, have been large in 1894, and, say, 1895, in 1911 and 1912, and in 1918 and 1919. At the present time it should contain more water than at any time "within the memory of the oldest inhabitant."

Droughts Minimised by Evaporation from Lakes.

In order to see if the records tend to confirm the theory that the evaporation from Lake Torrens is a large factor in bringing about the improved rainfall to south-east, or in lee of it, and between the lake and, say, Wentworth and Mildura, I tabulated the annual rainfalls at ten of the principal stations in this area, as well as at five to southwards, where no improvement is evident, and of five to northwards beyond the influence of Lakes Torrens and Frome as rain producers. The first (Group A) consists of Hawker, Warcowie, Holowiliena, Wilson, Belton, Paratoo, Yunta, Cavenagh, Johnburgh and Waukaringa; the second (Group B) of Port Augusta, Quorn, Wilmington, Arden Vale and Port Germein; the third (Group C) of Blinman, Beltana, Mt. Lyndhurst, Leigh's Creek and Wooltana. The percentage departures from the average rainfall during the years following periods of lake water accumulation were as follow:

	1894	1895	1911	1912	1918	1919
Group A.	+19	− 4	+ 7	+13	+ 2	+12
„ B.	+ 2	−18	−23	+10	−19	− 3
„ C.	+ 1	+13	− 3	−16	−25	−22

These figures show the apparent advantage to Group A from lake evaporation to be very marked, and they also show that the gain so striking during the decade 1910-1919 could not be attributed to the accidental excesses of wet years. The fact that owing to its position, Group B should have the most reliable rainfall gives the comparison additional significance.

Lake Frome.

This lake, when full, perhaps does not cover more than half the area of Lake Torrens. It is, nevertheless, then a very large body of water with a surface of greater extent even than Port Phillip Bay. It is filled from practically the same drainage area as Lake Torrens, and, therefore, should behave in much the same way. Unfortunately, there are no stations at all near it on the south-eastern side. About twelve miles due south from it, however, there is Frome Downs Head Station, which shows an increase of 27 per cent. for the decade 1910-19, over its average rainfall of $5\frac{3}{4}$ inches. At a radius of about 100 miles in a south-easterly direction are Boolcoomatta, Cockburn, Thackeringa, Broken Hill, Purnamoota, Poolamacca and Corona. These stations had in only two cases complete records for the period reviewed, but these records were capable of being "patched" without any large probability of error. All but one show marked improvements in the last ten years' rainfall, the percentages being respectively: +9, +11, —5, +13, +4, +3, and +23. The minus result was the most doubtful; but taking a mean of the lot, we get an average increase of 8 per cent.

Other Systems.

As regards the probable water accumulation in Lakes Eyre and Gairdner, or in the numerous minor lake beds of South Australia, nothing can at present be said. Lake Gairdner is probably under somewhat similar influences, but Lake Eyre derives its supplies from sources too remote, and an area too vast to permit of any hasty generalisation. It may be noted, however, that in connection with all these lakes there are indications of benefit during the decade 1910-1919 for all stations within areas south-east from them, and to some extent to south and south-west from them also. This, of course, is in accordance with results already shown by the analyses of the rainfalls on the eastern and western shores of the head of Spencer Gulf. Both gained from the waters between, but only in the case of the former could any great inland gain be expected, the general drift of the atmosphere being eastward.

The Cultivation of Eyre Peninsula.

Reference has been made to the improved rainfall over the eastern half of Kangaroo Island, the southern half of Yorke

Peninsula, and at Waratta Vale, in the east of Eyre Peninsula. In view of the expanses of sea included, it might seem absurd to connect these areas and to attribute the rainfall increases to any land improvements, but it is nevertheless true that such would be quite in accordance with what has been already described for other regions. Waratta Vale lies south-east from an area which has undergone rapid improvement during the last decade. In 1890 the counties Flinders and Jervois could only show 23,000 acres under cultivation, and it was only in 1906 that 100,000 was reached, but from 1910 to 1918 the average cultivation acreage was over 320,000 acres. This means much clearing of Mallee scrub. In Yorke Peninsula, too, the increase was very marked, amounting to more than 200,000 over the average acreage from 1890 to 1900, or from about 130,000 to 350,000 acres. This latter has recently become, owing to the use of fertilisers and improved methods generally, one of the most important granaries of South Australia.

Cultivation in the South-East and East.

The most rapid development in South Australian cultivation during recent years is in the counties Albert, Alfred, Chandos and Buccleuch, south of the Murray, and adjoining Victoria. Prior to 1908 the cultivation was almost negligible, less than 100,000 acres altogether. In 1916 their total was over 670,000 acres. Any rainfall improvement due to this would, however, mainly affect the adjacent Victorian Mallee areas, most of which are at present quite undeveloped. It is more than probable, however, that the improved rainfall shown about and south from Lake Hindmarsh is due to that. Moreover, in the recently developed Mallee areas along the Murrayvale-Ouyen line, the rainfall has proved better than was expected.

Explanatory Notes.

The objection might be raised that the great length of the rain improvement strip S.E. from Lake Torrens is out of all proportion to the area of the lake. This may be met by remembering that there may be many re-evaporations and re-descents as rain of the moisture obtained from the lake. Every moistening of any area helps the rain prospects for that in lee of it. Another point is that the hours of most active evaporation and precipitation are not the same. Thunderstorm rains are heaviest and

most frequent towards evening, and widespread rains of tropical origin seem to be helped by the atmospheric cooling during night-hours. Thus the effects of lake evaporation might be postponed for several hours, and be first felt one or two hundred miles away.

Map showing percentage departures of the mean rainfall of the last 10 years, 1910-1919, from that of the 30 year period, 1885-1914.

Rainfall Incongruities.

The apparently haphazard mixing of small plus and minus departures may often be due to difference in elevation and aspect of the rain stations used. For example, south from Lake Torrens and west from the Willochra valley is some fairly mountainous country on which the bulk of the rain would be caused by "southern" disturbances and accompanied by wind, whereas on the lower ground or in lee of the ranges, the rains would be more of "monsoonal" type. The latter would show the influence of the lakes, the former might not. Then, of course, we have to put up with the occasional neglect of the rain guage, observers' carelessness, varying faults in the exposure of the gauge, etc.

Evidences from Decennial Rainfall Maps.

In order that the decade 1910-1919 should not have to carry the whole burden of proof that rainfall is affected by changes in the surface of the country, I plotted the rainfall departure in similar fashion for each of the three decades, making up the standard period. The results are most interesting and quite in accordance with the theory.

1885-1894. Over the inland areas of South-eastern Australia, or east from a line joining Spencer Gulf, Lake Torrens and Lake Eyre, this was a remarkably wet decade. While this helped to fill the lakes in South Australia, and increased the floodings of the Murray and its tributaries, thus producing evaporation areas and increasing the rainfall in the favoured areas, the generality of the abundant rainfall, which was largely of direct tropical origin, tended to obliterate these local preferences. We can look, therefore, for smaller percentage gains over the areas usually favoured. This shows up quite well on the map. The following strips of country showed less gain than the country on either side: (1) Along the Murrumbidgee from its junction with the Lachlan, almost up to Narrandera; (2) From Yarrawonga to Deniliquin and Piangil, or along the upper Murray and Edwards; (3) From Shepparton, along the Murray to Wentworth; (4) From Wentworth to Lake Torrens. As regards the river areas, this tends to confirm the reality of the rainfall increases shown by the isohyets on the average annual rainfall map to obtain along the Murray and the principal streams through the Western Riverina. When the map was constructed, in 1910, this was regarded as a freak result. The actual percentage departures from average are as follows. Beginning with the plain country north of the Murrumbidgee, and ending with the Victorian plain country south from the Murray River we get: Plains (northern) +28, Murrumbidgee River +19, Plain +24, Edwards and Murray River (upper) +20, Plains +23, Murray River (lower) +17, Plains (Victoria) +24.

For the decade the greatest percentage increases are over the north-west and central plain country of New South Wales, where some reach 40 per cent. The dominantly tropical origin of the rains is obvious.

Stations along the Darling from Pooncarie to Wilcannia show very consistent increases of over 30 per cent., which may have

been partly due to the filling of the rarely filled lake system along the Darling.

1895-1904. Drought was predominant during this decade, and tropical influences on the whole ineffective. The very severe three years' drought which began in July, 1895, must have dried up the moisture in the lake beds, and there was no appreciable run-off to renew it until 1903. This being so, we should look for the area partially dependent upon the lakes for its rainfall to show the greatest deficiencies during this period. This is shown very well, the minus isopleths for this decade showing much the same contouring as the plus for 1910-1919. This reversal is even shown along the southern and south-eastern borders of the Mallee, which is at it ought to be, the Mallee still being largely wilderness or unimproved.

1905-1914. This being a transition period, both for agricultural development and lake storage, its isopleths do not stand out as those for 1910-1919, but similar tendencies are strikingly shown. The agricultural progress of Eyre Peninsula is apparently reflected in rising rainfall to south-east of the areas, that is, on the foot of Yorke Peninsula and the eastern end of Kangaroo Island; the Western Wimmera is gaining by the clearing and cultivation of the South Australian Mallee across the border; and the rainfall from Wentworth to Lake Torrens is distinctly on the up grade.

It supplies, moreover, another exceedingly neat proof of the effectiveness of the floodings from the Murray River system in increasing the rainfall on the river flats, the rainfall isopleths over the Riverina and northern Victoria, which were minus, giving an almost exact copy of those for the wet decade, 1885-1894, which of course were plus.

All three decades thus bring their evidence to support in various ways the theory that the rainfall is largely affected by local influences. The coincidences in areas affected are very striking.

Another point made clear is that the decennial rainfall oscillations are far greater east from the South Australian lake system than west of it, which is itself fairly strong evidence that the variation in the lake supplies is a large disturbing factor. The figures also suggest for inland New South Wales a rainfall dependence upon previous downpours in Queensland, and especially those tending to fill Lake Eyre.

The following table shows the decennial rainfall variations at two groups of stations, one on the western, the other on the eastern side of the lake system:—

Western Group.	1885 to 1894.	1895 to 1904.	1905 to 1914.	1910 to 1919.
Oodnadatta	+5	−1	−4	−15
Anna Creek	+0	−8	+9	−9
William Creek	−10	+2	+8	−12
Stuart's Creek	+5	−14	+8	−1
Arcoona	+5	−3	−2	−5
Coondambo	+1	−9	+8	+2
Means	+1	−6	+4	−7
Eastern Group.	**1885 to 1894.**	**1895 to 1904.**	**1905 to 1914.**	**1910 to 1919.**
Warcowie	+11	−19	+8	+11
Holowiliena	+13	−25	+13	+23
Belton	+14	−24	+10	+11
Paratoo	+19	−32	+13	+20
Frome Downs	+14	−31	+18	+27
Cockburn	+21	−20	−1	+11
Means	+15	−25	+10	+17

Seasonal Forecasting.

The effect on this cannot be ignored, since well-filled lakes are a guarantee that for a few years, two at least, the climate of the areas south-east from them will be greatly ameliorated—this can be taken account of by farmers and pastoralists, the latter more especially. For example, whatever the severity of any general drought over south-eastern Australia during the next two years, its effects should be distinctly alleviated over a large area south-east from Lakes Torrens and Frome, as well as over all northern Victoria, and some of the Riverina.

General Deductions.

The strength of the preceding reasoning lies, of course, in the general and striking accordance of the results obtained. Taken in conjunction with Victorian experience, these are so numerous that the case for definite rainfall improvements due to local sources may be regarded as definitely proved. It is the evidence we accept to demonstrate the rainfall effects of rising ground proximity to the ocean, prevailing winds, etc., for which we do not need many years' records. This solves the problem of what

should be done to revive the "dead heart of Australia." Without any far-seeing policy or consciously-directed effort on our part, it is probable that the great inland lakes will gradually store more and more water; but surely the process is worth hastening. For example, it might even be worth while to keep Lake Torrens at least partially supplied from Spencer Gulf. An improvement of 20 per cent. in the rainfall of 20,000 square miles of country is worth much money, a practical example of which is to hand. The counties Granville, Hanson, Herbert and Lytton, which form only a part of the improved rainfall area under discussion, in 1918 carried 387,000 sheep and nearly 11,000 cattle and 4000 horses, numbers practically equal to those of 1891, the record stock year for Australia.

Storage Gains from Clearing.

The preceding study teaches two important lessons. One is that the clearing away of the forest covering from the whole of our hilly areas, at all events, of those portions of the inland foothills and mountain slopes in any way suitable for pasturage, is distinctly beneficial, not only to its stock-carrying capacity, but to inland climatic conditions as well, inasmuch as it greatly increases the amount and constancy of the flow of the rivers. It thus releases from day to day for storage in inland lakes and reservoirs vast quantities of water which otherwise would be thrown into the mountain atmosphere, and to a large extent cross the hills, eastwards and southwards, without condensation, and so escape. A reason for thinking this is that the transpiration and evaporation from the leaves of the upland trees must be little or none during the times of atmospheric saturation, but are probably most vigorous during the bright sunshine and drier air of the anticyclonic periods. This seems contrary to the behaviour of the drought-resistant vegetation of the plains, which has to adapt itself to extreme conditions, but it is not really so. By mountain vegetation, more especially that of Victoria and New South Wales, the strain of drought and heat is rarely felt and so definite drought resistance is not often called for; whereas saturated air is a rare experience to the Mallee eucalypts and their fellow strugglers, and heat and aridity so often have to be endured that transpiration, if not checked, would exceed the powers of their roots to make good. From the former, evaporation is inopportune, both in time and place—from the latter in time.

Need for a National Policy.

The other is that every facility should be given to settlers to make payable use of our remoter inland areas, even to the extent of national financial, and other sacrifices, recognising that this occupation of the interior is a sure way of ameliorating the climate for the rest of the continent or, at all events, for all those areas in lee of the outpost belt. Obvious methods are, of course, the adoption of some zone system for railway fares and freights, and the establishment of the greatest water schemes the continent is capable of. The addition of four or five inches of rain to the average annual rainfall of our dry areas, especially if the addition were maintained during drought periods, would mean multiplying their value by 20 at least.

It is evident, too, that the further inland the water can be stored or utilised, the more extensive will the area benefited climatically be.

Tropical Origin of Inland Rains.

Keeping Lake Torrens full would evidently help to keep Lake Frome full also, the latter draining a very large proportion of the country benefiting. If we consider the origin of these inland rains, and the processes at work in their production, this statement will prove not so extravagant as it seems at first sight. The mapping of the daily departure from normal of the minimum temperatures at all stations over the northern half of the continent shows that practically all the inland rains are of tropical origin. That is, rain never falls, say, in the neighborhood of Lake Frome without previous evidence of a drift towards this region of a body of relatively warm, moist air from some northerly point, most often, presumably, from the north-west. Condensation is usually the result of latitudinal cooling, and may take place without the assistance of any storm developments, though it most often occurs in the north-eastern front of "southern" disturbances which naturally accelerate the southward drift of the air in front of their troughs. It is occasionally helped too by what appears to be displacement upwards of this warm air by the cold, dry air of an anticyclonic system moving inland from some point south of west. But whatever the outside accelerating influences, it is certain that evaporation from any considerable body of water in the path of this southward-moving air will have a powerful effect in deciding where and when precipitation shall begin. Assuming, say, that we have, as these

minimum temperature departures so often show, a wide flow of air coming inland from the neighborhood of Wyndham or Port Darwin, this may carry its water vapour without much addition from the dry plains beneath for perhaps 2000 miles before it shows by its cloud production that through gradual cooling the limit of its moisture-holding capacity is nearly reached. Precipitation may not begin till the Murray is reached, or even the highlands of the Divide, but it might begin considerably earlier, and perhaps two or three hundred miles further inland if it encountered the disturbing effect of buoyant, moist air rising from such a source as L. Eyre or L. Torrens. That is, for large inland areas, the influence of the lake evaporation helps to determine not only the amount of rain, but perhaps more often whether there shall be some rain or none. In a sense it may be partly a question as to when and where "the tap is to be turned on."

Australia's Increasing Aridity—a Partial Cause.

In these papers, reference has already been made to the different ways in which vegetation may affect rainfall. It has first been shown that the substitution of growing cereal crops or grass for Mallee scrub causes a marked increase in the rainfall of the districts in lee of the improved area, especially in spring. Then irrigation was proved to show some similar effects. And now I have been able to show greater effects still, from the recently increased water storages in the great lakes of South Australia, the benefits being almost on a continental scale. For the increasing lake water storage, the changing character of the natural drainage channels, and the lessening of the water demands of the forest covering under pastoral occupation have been shown to be important factors. We may now logically apply these results to the solution of a larger problem.

The early settlers in the eastern interior of this continent found inland perennial vegetation to consist first of a belt of vigorous growing trees with abundant foliage occupying the more elevated upland regions; next on the foothills and adjacent plains the hardier types of the same with smaller leaf surface; then further inland stunted and distinctly drought-resistant types, such as Mallee eucalypts, bull-oaks (casuarinas), etc.; and further inland still, under severer conditions, salt bush, blue bush, etc.

Now it is more than probable that in the struggle for existence our perennial vegetation has been its own undoing. The very means it has been compelled to take for its own protection have made the climatic environment progressively worse. Whether distinctly drought-resistant or not, it must regulate transpiration so that it is never unduly accelerated with the result that the hot spells leading up to rainy conditions find inadequate response in evaporation from the country beneath, while the comparative coolness of the shaded land surface helps to prevent convectional action and lessen the frequency of thunder-showers. Moreover, the blocking of the water channels and the prevention of erosion, the drying of the subsoil, and consequent lessened flow from springs owing to the large moisture requirements of the trees all tend to hold the water up against the eastern mountain slopes, where its evaporation is comparatively ineffective in rain production, and away from the depressions in the interior where its evaporation would be most effective in rain production. Hence the increasing dryness of the interior and the gradual contraction of the belt of perennial vegetation towards the inland slopes and foothills.

It therefore follows that pastoral occupation must be assisting to reverse the process of dessication. The destruction of the forest trees in the more favoured belts, and the substitution of grass and annuals for the more drought-resistant trees, and even for the scrub and herbage perennial growths inland, are aids in the local production of rain, while the firming of the surface soil and the formation of tracks to water by stock help to make surface drainage better. Then the tapping of artesian and sub-artesian water supplies, though probably only a minor influence, must help to increase atmospheric vapour supplies and tend to rain production. Much injury is in parts unfortunately being done to the fine surface soil covering of the plains, but where the plough is used this is arrested.

The filling of Lake Eyre though a most attractive proposition, is perhaps an impracticable one, but water storage and irrigation for large portions of the north-western and western divisions of New South Wales seem possible, and if carried out whole-heartedly, would surely have beneficial results to the inland climate of that State almost incalculably great. The addition of two inches of rain annually seems quite possible, and that would carry wheat cultivation westwards to the Darling River.